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DATA ON AGE AND LONGEVITY IN *GALLOTIA GALLOTI* (SAURIA, LACERTIDAE) ASSESSED BY SKELETOCHRONOLOGY

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ABSTRACT

Femurs of 73 *Gallotia galloti* caught in different localities and belonging to two subspecies living in Tenerife (Canary Islands) were analysed by skeletochronology. The bones possessed annual rings like in many other lizards. For a high percentage of individuals, a remnant of the embryonic bone and a birth line of arrested growth remained present throughout life because cortical resorption never completely removed the first annual rings. Thus the age of an individual can be directly calculated from the number of lines of arrested growth. In the sample studied here, the oldest lizards were at least 8 or 9 years old. They reached sexual maturity during their second or third year of life.

INTRODUCTION

There are many papers on distribution, systematic, phylogeny, microevolution (e.g. Böhme & Bings, 1975, 1977; Böhme & Bischoff, 1976; Böhme *et al.*, 1981; Molina Borja, 1981; Bischoff, 1982, Castroviejo *et al.*, 1985; Baez & Thorpe, 1985; Thorpe *et al.*, 1985) and some behavioural aspects (Böhme *et al.*, 1976) of the extant lizards of the genus *Gallotia* (Arnold, 1973) from the Canary Islands. In a special symposium, recently held in Germany (Böhme & Hutterer, 1985), on the herpetofauna of Canary Islands, more than half of the twenty six papers presented dealt with the extinct and living species of *Gallotia*. Studies on the ecology of these lizards are still scarce though.

In this preliminary paper, the subspecies *G. g. galloti* from the south slope of Tenerife Island and *G. g. eisentrauti* (Bischoff, 1982), from the north slope of the Island were studied. The species occupies the most diverse habitats on the island, from the seashore up to the highest peaks (maximum altitude: 3717 m). The density of the populations is normally very high. These lizards are omnivorous although adults are predominantly frugivorous, whilst young are predominantly insectivorous. The reproduction in *G. galloti* begins in spring and continues throughout the summer when the first young animals appear. The number of eggs laid by the two subspecies studied varied between three and six.

The method used to assess age, longevity, time of maturity and growth pattern was skeletochronology (Castanet *et al.*, 1977). This method has already been used in many other lizards studies (e.g. Smirina, 1974; Pilorge *et al.*, 1981, Castanet, 1982; Nouira *et al.*, 1982; Cheylan, 1984; Castilla & Castanet, 1986).

MATERIAL AND METHODS

The genus *Gallotia* is endemic to the Canary Islands and comprises four extant species: *G. simonyi*, *G. stehlini*, *G. atlantica*, and *G. galloti*. The latter inhabits the islands of Tenerife, La Palma, La Gomera and Hierro. For more information see Baez (1984). A total of 76 *G. galloti* (39 adult males, 23 adult females, 14 juveniles of unknown sex) of various sizes were caught in different months of the year and from different places and altitudes on Tenerife (Fig. 1). The lizards, were preserved in 70 per cent alcohol and were also used for other biological studies. All specimens were of unknown age. A preliminary skeletochronological analysis was made on four lizards (not included here) to determine whether the femur, the humerus or the phalanges had the most reliable bones growth pattern for the purposes of this study. The femur, where skeletal growth marks have the most legilibility, was chosen for the whole sample analysis but use of phalanges in future ecological studies remains a real possibility in this species. After removing the muscles, the femurs were demineralised for 10 hours in 5 per cent dilute nitric acid. A section measuring about a quarter of the length of the bone was removed with a razor blade at the level of the diaphysis. The bones were cut with a freezing microtome into sections of twenty μm thick. They were stained for thirty minutes with Ehrlich's hematoxyline. The mid diaphysis had the highest ratio of external diameter to medullary cavity and so provided the best definition of the lines of arrested growth. About twenty sections from the mid of each individual diaphysis were mounted with aquamounting medium for microscopic examination. For accurate comparison, one slide of each individual was photographed at the same magnification.

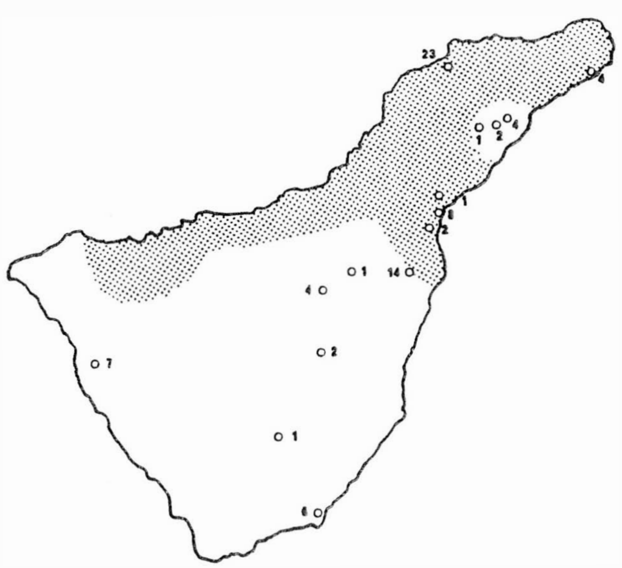


Fig. 1 Tenerife. Number of lizards from each site. Shaded area = distribution of the subspecies *G. g. eisentrauti* (38). *G. g. galloti* are in the white area (42).

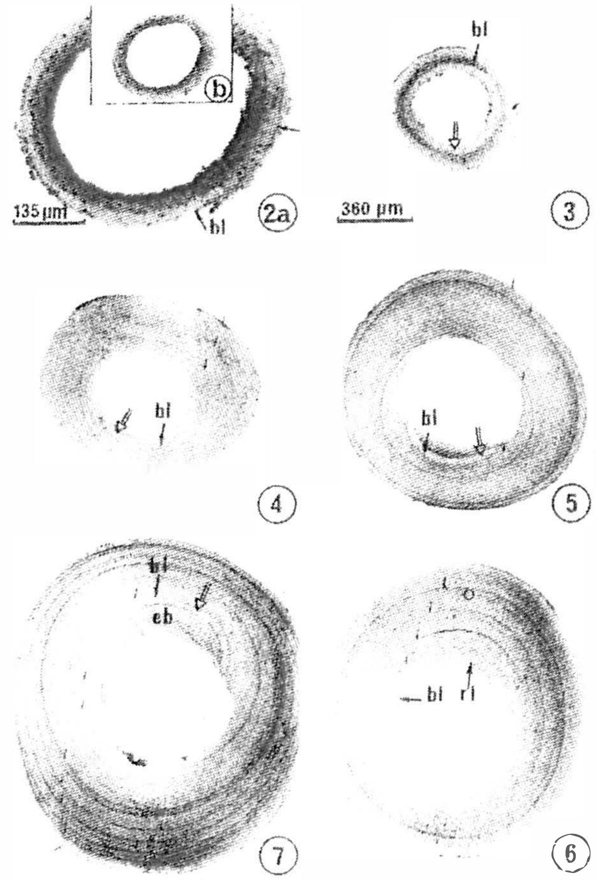
RESULTS

The bone structure of *G. galloti* was similar to that of many other Lacertidae. In the femoral or humeral diaphysis the periosteal cortex was avascular and consisted of a compact parallel-fibred bone tissue. In some old individuals this bone can become sublamellar. In the phalanges, the diaphyses were commonly composed of a true lamellar bone tissue. This histological difference (e.g. Amprino, 1947; Ricqlès, 1968, 1975, 1976; Castanet, 1982; Castanet *et al.*, 1987) indicated that the rate of bone deposition was lower in the phalanges than the femur or the humerus.

All three bones showed an endosteal resorption process. For juveniles younger than one year and some older lizards, this resorption process was seen in only one part of the medullary cavity. On the other part we observed the deposition of endosteal and typical lamellar bone laid down after a small bit of resorption (e.g. Fig. 7). A typical scalloped cementing resorption line separated this endosteal bone from the outer periosteal cortex (Fig. 6). This overall remodelling process lead to the progressive drift of the bone centre during growth.

On the reconstructed side, the embryonic bone was always partially preserved, even in the oldest specimens. As in many other lizards, this embryonic cortex was made of a rather woven fibred bone tissue and appeared clearer (i.e. less hematoxylinophilic) than the other part of the outer periostic cortex (Figs. 3, 4, 7). Hematoxylinophilic Lines of Arrested Growth (LAGs) were present in every bone and showed different patterns of spatial arrangement (Figs. 3, 4, 5, 6, 7). For the species used in this study we lack data concerning the exact periodicity of the LAGs, but previous studies with temperate reptiles and amphibians (e.g. Francillon, 1979; Buffrénil, 1980; Hemelaar, 1981; Castanet, 1985; Francillon & Castanet, 1985; Hutton, 1986; Zug *et al.*, 1986) have shown the annual (winter) LAG deposition. We assume *a priori* that LAGs were also annual for *G. galloti*. In most of the lizards examined, LAGs are generally well defined. Sometimes they appear as a double line (e.g. Fig. 7) which generally indicates a single year of growth (Castanet, 1982).

In all specimens we observed a first dense hematoxylinophilic line surrounding the embryonic bone. There was the single LAG present for the three lizards caught in November (No. 456 — Fig. 2), February (No. 96) and March (No. 160). On the basis of their size, proportions and date of capture these lizards were considered to be less than one year old. We presume that in the genus *Gallotia*, this line which surrounds the embryonic bone corresponds to a hatching line, as in other lizards previously examined (e.g. Smirina, 1974; Castanet, 1985). For lizards No. 96 and No. 160, osteogenesis probably had not started when they were caught. This might explain why the LAG of the first winter (which probably corresponds



Figs. 2 to 7 *Gallotia galloti* Successive growth stages of the femoral shaft. Each picture except for No. 2a is at the same magnification. Fig. 2a and 2b Lizard No. 456. Young of the year caught in November. A single LAG, birth line (bl), can be seen near the periphery of the bone. Fig. 3 No. 12, Juvenile caught in July and probably about one year old. The birth line and this of the first winter can be seen. The white arrow shows the embryonic bone. Fig. 4 No. 210, caught in April. Three LAGs. 2 to 3 years old (according to the unknown birth date). The third is very near the periphery of the bone. Embryonic bone is present. Endosteal bone deposition is just at the beginning (e. b.). Fig. 5 No. 172, caught in March, 4 LAGs. 3 to 4 years old. Fig. 6 No. 44, caught in August. 4 LAGs. About 4 years old. The spatial sequence of year rings is different from that of Fig. 5. Bone deposition is probably not yet finished at the periphery. Notice an additional hematoxylinophilic line close to the LAG No. 4 (circle). Fig. 7 No. 32. One of the oldest lizards caught in August. 8 LAGs can be counted. The LAG of the first winter is thin. The fourth and the eight are double. This specimen is at least an 8 year old one. e.b. = endosteal bone.

to the time of decreasing growth rate for *G. galloti*) is not yet distinct from the bone periphery.

For all the other individuals which had experienced at least one winter and which were caught during their growth period (April, May, June . . .), the bone beyond the birth line generally showed a LAG which corresponds to the first winter (Fig. 3). Depending on the individual, the birth line and the first winter LAG appeared close together or well separated. Below we discuss the significance of this feature. In general, LAGs 1 to 3 or 1 to 4 were separated by a large increment of bone due to the very fast bone growth from the first to the third (or fourth) year of life. After the third or fourth LAG, the bone thickness between successive LAGs decreased (Fig. 7). This phenomenon was related to the decrease in growth rate of adults. This 'break' in the spatial sequence of the LAG (e.g. Castanet, 1982) suggests that in *G. galloti* sexual maturity is reached before the third or the fourth year of life.

In the present sample, the oldest lizards (Nos. 30; 32) showed 8 (or 9) LAGs (Fig. 7). Therefore ecological longevity of *G. galloti* was at least 8 or 9 years.

DISCUSSION

In the present study we noticed that the size of lizards progressively increased with age until the third to fourth age group (Fig. 8). After this age we observed very little further growth in adults. This is a general phenomenon in poïkilothermic animals after sexual maturity. It indicates once again that size cannot be a reliable criterion for age determination in lizards.

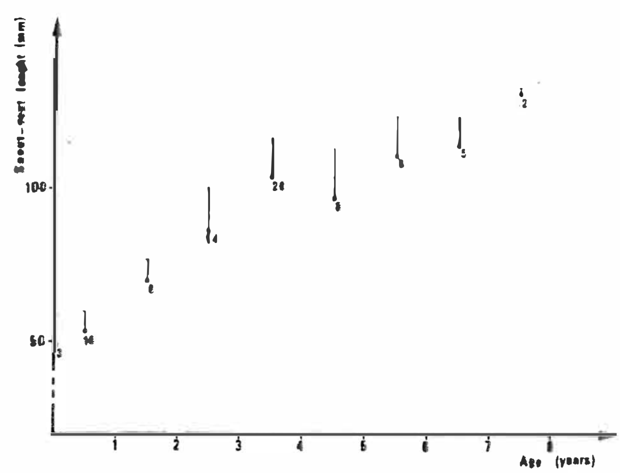


Fig. 8 Growth curve of *Gallotia galloti* from Tenerife. Each point corresponds to the average of individual sizes (and standard deviation) for the different age groups estimated by skeletochronology. Because of the small number of animals and their heterogeneity (2 subspecies, different altitudes, males and females) it was not possible to separate the different categories.

One of the main problems encountered in this analysis and already discussed in relation to many other species of lizards was the position of the first year LAG and its relation to the birth line. The thickness of the bony crown between these two lines corresponds to the duration and intensity of growth during this period (Pilorge & Castanet, 1981; Nouira *et al.*, 1982; Castanet & Gasc, 1985). As growth stops at the same time of the year (generally in winter), it appeared that the hatching period was spread throughout much of the early spring up to the beginning of autumn. However, in few individuals, the distance between the birth line and the first LAG was so large that it can only correspond to a full one year growth. In these conditions, the first LAG encountered would belong to the second season of arrested growth. Two hypotheses can be proposed here. First, the lizard was hatched late in autumn and no osteogenesis occurred until the first winter. In this situation the birth line and the first winter LAG would be merged. Second, as already stated before, the LAG of the first winter is generally less distinct than the later ones (Castanet & Gasc, 1985; Castilla & Castanet, 1986) or, sometimes, completely lacking. This phenomenon could be related to the continuation of the growth during the first winter, owing to the strong intrinsic growth of the juveniles, which would reduce the influence of the adverse environmental conditions. However, presently there are no rigorous data to test these hypotheses although based on lizards 160, 456 and 96, the first hypothesis seems here better than the second one. Consequently, for some individuals, the age of the first LAG beyond the birth line remains uncertain, and their age is estimated with a potential margin of error of one year.

In our sample, males and females from both high and low altitudes sometimes showed double randomly distributed LAGs (Fig. 6, 7). The cause of this remains uncertain (Castanet, 1982). Briefly, it may be related to individual variations, pathologic injury or atypical climatic conditions. It may also correspond to two periods of arrested growth in a year (hibernation and a estivation; see Caetano *et al.*, 1985). We suggest that the latter explanation is plausible for at least some individuals but confirmation would have to come from appropriate field observations. Anyway, taking account of previous results and experimental data on lizards (e.g. Castanet, 1982, 1985), each double LAG observed can be counted as one year without ambiguity. Thus the error in age determination for individuals with such supplementary LAGs cannot exceed one year.

Another phenomenon encountered in this histological analysis was the great variability of the spatial arrangement of the LAGs. Two main patterns were recognised. In the first case, all LAGs were relatively close together, and in the second case they were very far apart. It is difficult to interpret this variability between the different individuals and to propose some causal relation with any particular parameter such as sex or environmental conditions because the two patterns are shown by a rather equal number of males and females or lizards from different altitudes, or from the south and the north of the Island. Of course several factors may explain such features. One of them is the variation of growth rate directly related to the genetical programme of each individual. Another factor may be connected with the individual competition for food. In fact, in Tenerife, the population density of *G. galloti* is very high (in some places it reaches more than 500 individuals/ha), and perhaps the supply of food is insufficient for all the lizards, although Molina Borja (1985) found a great food availability in the areas where he studied *G. galloti*. Moreover we must not forget that the sample studied here does not come from a homogenous population and finally that in the various places where the lizards were caught, the microclimates are often different and can lead to some differences in the individual growth patterns. In order to make a more meaningful comparison of the spatial sequence of LAGs, it would be better to use individuals from the same locality.

The intensity of endosteal resorption in *Lacerta lepida* (Cheylan, 1984; Castilla & Castanet, 1986) leads to the removal of the first and sometimes the second LAG, and occurs along the entire border of the medullary cavity. In *G. galloti*, the endosteal resorption was eccentric (Fig. 7) and consequently a part of the embryonic bone and the LAGs beyond it, permanently remain in some regions throughout life, except in 2 per cent of the lizards. In *L. lepida* the endosteal bone deposition is scarce or lacking, but in *G. galloti* some lamellar endosteal bone occurs just beside the embryonic bone in adults. This fact is interesting because: first, for *G. galloti* no 'back calculation' to assess the age of the first line encountered is necessary (e.g. Castanet & Cheylan, 1979); second, this histological difference probably constitutes a distinctive character between two species (*L. lepida* and *G. galloti*) closely connected by size, growth and longevity. This character could be very useful in the case where only the bones from fossils specimens would be available.

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